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Strongyloides fuelleborni kellyi in New Guinea: neglected, ignored and unexplored

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Abstract. Strongyloidiasis remains endemic throughout the Island of New Guinea. While many infections are caused by *Strongyloides stercoralis*, a second human-infecting *Strongyloides* species, *Strongyloides fuelleborni kellyi*, is also present. *S. f. kellyi* infections are most common in infants and young children, and those with high-intensity infections might develop a potentially fatal protein-losing enteropathy, swollen belly syndrome. Surprisingly little work has been performed on *S. f. kellyi*. Unlike *S. stercoralis*, *S. f. kellyi* is passed in faeces as eggs rather than rhabditiform larvae. There is no specific diagnostic test. This review summarises what is currently known about the biology, epidemiology, and clinical impact of *S. f. kellyi* infections. Features that might be used to differentiate *S. f. kellyi* from hookworm and *S. stercoralis* are also discussed. *S. f. kellyi* remains a neglected, ignored, and unexplored human helminth infection, worthy of further research.

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The Western Pacific region has among the highest burden of strongyloidiasis in the world[1]. While *Strongyloides stercoralis* is endemic in Papua New Guinea (PNG), the island also harbours a second human-infecting *Strongyloides* species, *Strongyloides fuelleborni kellyi*.

The presence of a previously undescribed *Strongyloides* was first identified by Allan Kelly of the PNG Institute of Medical Research in 1971[2]. Due to close morphological resemblance to *S. fuelleborni fuelleborni*, a parasite of humans and non-human primates in Africa and Asia, the species was originally described as a *Strongyloides fuelleborni*-like helminth, later changed to *S. f. kellyi*. Sequencing of the 18S ribosomal RNA gene revealed clustering at this target within a distinct clade including *S. cebus*, *S. papillosus* and *S. venezuelensis* but separate from *S. f. fuelleborni*[3].

Infection is primarily found in infants and young children, with egg loads peaking at 20 months of age[4–8]. High-intensity infection in infants <2 years of age can cause a rapidly fatal disease known as swollen belly syndrome (SBS), characterised by gross abdominal distension and respiratory distress[8]. SBS is most commonly seen in infants around 2 months of age[8]. The characteristic swollen belly observed in this condition is due to ascites following a protein-losing enteropathy. The signs and symptoms of SBS include a very low serum protein, ascites, peripheral oedema, mild diarrhoea with very high numbers of *S. f. kellyi* eggs in faeces, occasional vomiting, a high-pitched cry, fever (in some cases) and respiratory distress[8]. Haemoglobin levels remain normal[8]. Heavy infections in older children may be associated with failure to thrive, but many older children appear asymptomatic[8].

Strongyloides fuelleborni kellyi has been found in multiple provinces of PNG[7] and has also been reported from Irian Jaya in Indonesian Western New Guinea[5]. No work has been performed on the distribution or prevalence of this parasite since 1997[9]. Historical surveys conducted between 1981 and 1997 reported prevalence in children from endemic areas ranging between 20% and 93%, with most studies finding a prevalence of over 60% in children aged <10 years[4,6–13]. Prevalence peaked between 20 and 36 months of age[4,6]. Prevalence in children from high-intensity infection communities may reach 100%[4,8] and it was not unusual in such communities for children to pass more than 100 000 eggs per mL of faeces[8]. Prevalence rose steeply from 1 month to 4 months of age[6], but by 10 years of age prevalence fell and the intensity of infection rarely exceeded 500 eggs per mL of faeces[8]. Prevalence in adults from affected communities was only 5–10%. The parasite was found infecting people in both rural and remote communities, and larger towns and cities[6], although with a much lower prevalence in urban areas[4,12]. Environmental factors such as altitude, slope of ground, landform, rainfall and population densities do not influence distribution of the parasite, although it is uncommon in areas with limestone and polygonal karst[7]. It is not known if an animal reservoir of infection exists[8]. Pigs were investigated extensively as a potential zoonotic source but no *S. f. kellyi* infections were found[14].

In high prevalence communities, patent infection may occur in infants only 14–18 days old. The exposure of infants to filariform (infective) larvae in soiled bedding used to line string bags in which they were carried might have led to rapid external autoinfection, causing the very high-intensity infections seen in this age group[8]. Internal autoinfection, which is seen in *S. stercoralis* infections, is thought not to occur. This is because *S. f. kellyi* are passed as eggs in faeces, unlike *S. stercoralis*, which are passed as larvae[8,15]. Also, prevalence and egg counts are observed to decline with age[4,6,7,9,11,13], indicating that maintenance of infection via an auto-infective process is likely not occurring.

S. f. kellyi eggs average 51.4 (47–55.8) µm in length by 32.1 (31.1–33.1) µm in width[15] and contain well developed larvae[8] that hatch within hours of passage[8]. In asymptomatic adults, these are normally single eggs free in the faeces (JM Shield, personal communication). However, in children with heavy infections, strings of eggs encased within a fine membrane (Figure 1)[8,15] or masses of eggs (Figure 2) may be seen[8]. The hatched larvae are morphologically indistinguishable from those of *S. stercoralis*[15].

Diagnosis of infection in very young infants may often be missed or delayed as it is generally assumed by clinicians that children of this age cannot yet have acquired intestinal helminths[8]. Misdiagnosis as hookworm is common due to the similar morphology of eggs[8]. Diagnosis from faeces is reliant on the presence of proficient microscopists who are aware of the existence and morphology of *S. f. kellyi* eggs, which are smaller and more developed upon passage than those of hookworm.

The parthenogenic adult parasitic female of *S. f. kellyi* appears to be morphologically indistinguishable from *S. f. fuelleborni*[15]. It may be differentiated from *S. stercoralis* by the presence of spiral rather

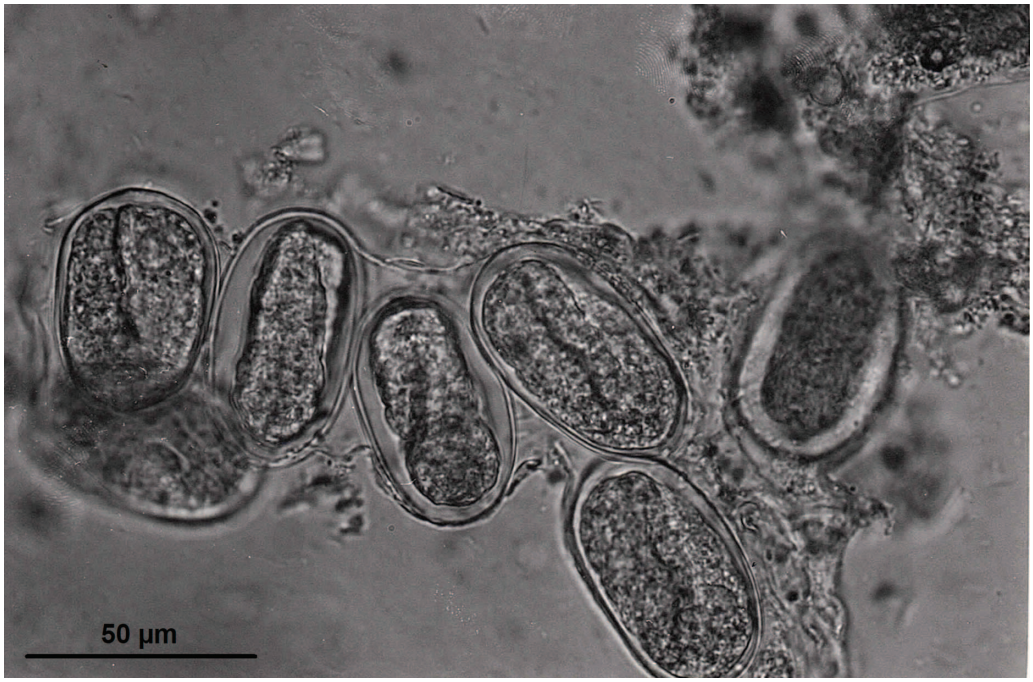

Figure 1. *Strongyloides fuelleborni kellyi* eggs (~51 × 32 µm) within a mucous membrane string, saline wet mount (image by Dr Paul Crouch-Chivers, courtesy of Dr Jennifer Shield, La Trobe University).

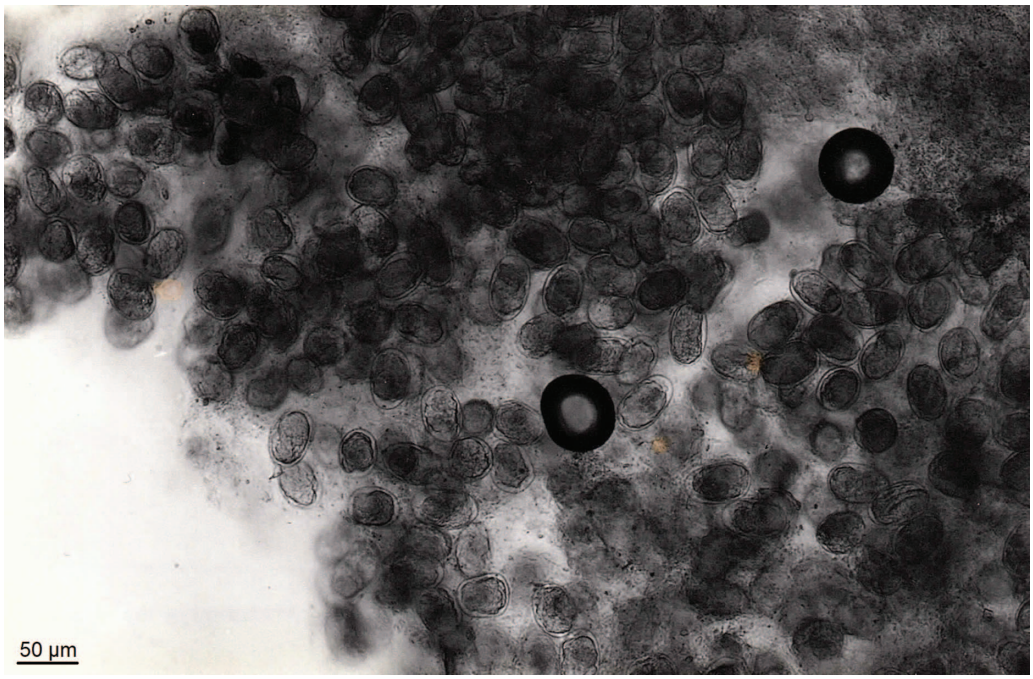

Figure 2. *Strongyloides fuelleborni kellyi* egg mass in a child with high-intensity infection, saline wet mount (image by Dr Paul Crouch-Chivers, courtesy of Dr Jennifer Shield, La Trobe University).

than straight ovaries[15]. Due to the difficulty in obtaining adult parasitic females this approach is not viable for routine diagnosis. *S. f. kellyi* may be differentiated from *S. f. fuelleborni* and *S. stercoralis* in its cultured free-living adult stage. Like *S. f. fuelleborni*, the free-living female of *S. f. kellyi* has a prominent post-vulval constriction, which is not seen in *S. stercoralis*[15]. There is also slight variation in the morphology of a portion of the peri-vulval cuticle of the *S. f. kellyi* free-living female when compared to that seen in *S. f. fuelleborni*[14]. Differences in the morphology of free-living males involve a more anterior position of the phasmidal pore relative to the sub-ventral, sub-dorsal post-cloacal papillae[14]. Detection and differentiation of these very subtle morphologic differences requires a very advanced level of parasitological expertise.

A treatment intervention study using thiabendazole (25 mg/kg twice daily for 3 days) was conducted between 1983 and 1984. This study found that thiabendazole eliminated egg passage in 86 of 88 infected children, with a very significant reduction in egg passage in the remaining two participants[16]. Reinfection after treatment was common[6]. Fifty-eight percent of treated children were found to be reinfected 18 months after treatment[6]. The modal time for reinfection was 9 months[6]. The standard treatment in PNG for *Strongyloides* in adults in PNG is albendazole 400 mg daily for 3 days[17]. Standard treatment for children with anaemia and oedema is albendazole 200 mg for those 5–9.9 kg and 400 mg for those ≥10kg daily for 3 days. Oedema in this context may include SBS due to *S. f. kellyi*[17]. The efficacy of ivermectin, moxidectin or combination anthelmintic therapies against *S. f. kellyi* has not been explored.

Very little work has been performed on *S. f. kellyi* in the past 30 years. Important questions, such as what is the current prevalence and distribution, and if it might be a zoonosis with an animal reservoir, have not been answered. This human helminth remains neglected, ignored, and unexplored, despite being present and likely widespread in Australia's nearest neighbour.

Conflicts of interest

The author declares no conflicts of interest.

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Biography

Richard Bradbury is a Senior Lecturer in Microbiology and Molecular Biology at Federation University Australia. His areas of research interest include diagnostics and epidemiology in medical parasitology and zoonoses.

Getting help to those who need it

Today, when we are anxiously watching who is being vaccinated and who is not, who can access COVID-19 vaccine and who can't, it may be a comfort to read of two other Herculean efforts to protect people from infectious disease.

The first story is from Nome, Alaska.

No need for a cold chain

Diphtheria was once a major cause of illness and death among children but, since the introduction of effective vaccination, rates have dropped dramatically. Before the vaccine was developed the only available protection was to administer antiserum. This treatment was discovered in 1890 by Kitasato and Behring.

In 1925 a diphtheria epidemic was spreading in Nome, Alaska. A train transported much needed antiserum as far as it could from Anchorage to Nenana but it was another 1084 km to Nome, without any rail tracks or roads. The decision was made to use teams of sled dogs and their mushers to get the antiserum to Nome. There is a statue in Central Park in New York City of Balto, the most famous of these dogs.

Now known as the last great race on earth the Iditarod Trail Sled race commemorates that long journey from Anchorage to Nome, a distance of 1500 km.

The second story is from north Western Australia.

The sugarbird lady

Robin Miller was a lauded West Australian pilot and Royal Flying Doctor Service (RFDS) flight nurse who brought polio vaccine to West Australians, especially Aboriginal children, who lived in the remote parts of the state. Most city dwellers had been vaccinated but country folk had not.

After obtaining a private pilot licence and a commercial flying licence while training as a nurse, Robin approached the Western Australian Department of Health to ask permission to fly to northern Western Australia in order to carry out a vaccination program. She borrowed the money to buy a Cessna 182 Skylane plane and throughout the late 60s and early 70s was constantly in the air , whether it was on a solo flight from Paris to Perth or working for the RFDS across the Kimberley and Pilbara.

Using the well known adage that a spoonful of sugar helps the medicine go down, Robin would drip Sabin vaccine onto sugar cubes and had no difficulty persuading children to take them. Her nickname, the sugarbird lady, was obviously a result of this activity. All in all she administered 37 000 doses of Sabin vaccine, mostly to Aboriginal communities, and also treated those with trachoma.

Robin kept detailed dairies that became the foundation for her two books, *Sugarbird Lady* and *Flying Nurse*. After achieving so much in providing health services to remote northern Australia and changing attitudes towards women in aviation, Robin is buried in Broome Cemetery. Sadly she died at the age of 35 from melanoma.